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Efforts to Improve Scientific Literacy Capabilities in Indonesia: Systematic Literature Review

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Abstract

Science literacy is an essential skill needed by students to face the challenges of globalization and technological development. However, the level of science literacy in Indonesia is still below international standards. The aim of this research is to know the efforts that can be made to improve science literacy skills. The method used is a systematic literature review (SLR). The Scopus database was used to search for the reviewed articles. Scientific literacy was used as the search keyword and limited to the last 5 years. A total of 26 articles were obtained from the screening process out of 1355 documents. The collected literature was then analyzed qualitatively. The findings show that the integration of technology such as Virtual Reality (VR) and e-learning platforms has great potential in enhancing students' understanding and engagement in science literacy. In addition, innovative pedagogical approaches, such as project-based learning and STEAM (Science, Technology, Engineering, Arts, and Mathematics), have also proven effective in improving science literacy.

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INTRODUCTION

It is important to develop 21st-century skills to prepare individuals to face rapid developments in technology and information (Sari et al., 2022). Scientific literacy skills are one of the most important competencies in facing the challenges of the 21st century (Hartono et al., 2023; Winarni et al., 2024). Scientific literacy not only includes knowledge and understanding of scientific concepts, but also involves the ability to think critically (Almeida et al., 2023; Sutiani et al., 2021), reasoning (Ardiyanti et al., 2019), solve problems (Effendi et al., 2021; Priadi et al., 2021), and make decisions based on scientific evidence (Al Sultan et al., 2018; Li et al., 2020; Ustun, 2024). Developing scientific literacy skills is the urge for students to improve communication skills and creative thinking (Irawan et al., 2023). However, several studies reveal that students' scientific literacy abilities in Indonesia are still relatively low (Hartono et al., 2023). A study of grade 5 students in Indonesia revealed that 60% of students were still at a level below the international average (Suryanti et al., 2018). This is caused by factors such as non-contextual learning and

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students' low reading ability (Hartono et al., 2023). This indicates that the education system in Indonesia has not succeeded optimally in guiding students to achieve adequate scientific literacy.

Various factors influence the low level of scientific literacy in Indonesia, including a lack of interest in science (Ustun et al., 2022), teaching approaches (Bellová et al., 2018), and limited facilities that support the development of skills in the science process. Low interest in reading among students also contributes to low scientific literacy (Palines & Ortega-Dela Cruz, 2021). The lack of training and professional development for science teachers, who often still use traditional teaching methods that are less interactive, is also an important factor (Suyatno et al., 2023). Low access to quality digital learning resources, especially in rural and remote areas, exacerbates this problem, considering that digital literacy is increasingly important in modern science education (Hu et al., 2018). Students often lack opportunities to engage in in-depth practicum activities and research projects that can significantly improve their understanding of science concepts (Hernawati et al., 2019). Therefore, it is important to identify strategies and efforts that can be made to overcome these challenges.

Identification can be done using a systematic literature review. Systematic literature reviews allow researchers to synthesize and analyze the existing literature in a particular field, providing a thorough and unbiased picture of the stage of knowledge on the specific topic (Deksne & Litavniece, 2022). This method helps in reducing bias by using a transparent and reproducible approach to identify, assess, and interpret all relevant evidence related to a particular research question (Higgins & Green, 2008). By conducting a systematic literature review, researchers can identify, review, and combine findings from multiple studies, facilitating the retrieval and integration of existing information to guide future research directions this process not only provides a solid foundation for the development of the theory and research frameworks, but also helps identify gaps in the existing literature, which can be the focus of further research (Liberati et al., 2009).

Previous research has conducted systematic literature reviews on various aspects of scientific literacy. Some of them are conceptualizing scientific literacy (Busch & Rajwade, 2024), which defines and outlines various components of scientific literacy in the context of modern education. In addition, the research (Kumar et al., 2024) explored the context of environmental socio-scientific issues in developing scientific literacy, emphasizing the importance of understanding science in dealing with complex environmental problems. Research (Istyadji, 2023) focuses on developing a scientific literacy assessment tool, which provides an evaluation tool that can accurately measure students' scientific literacy abilities. On the other hand, (Semilarski & Laius, 2021) examines biological literacy, providing in-depth insight into how students understand biological concepts and how this affects overall scientific literacy. However, there is still no research that specifically reviews systematic literature regarding efforts to increase scientific literacy skills in Indonesia. Therefore, this research aims to systematically review existing literature regarding efforts to increase scientific literacy in Indonesia and provide recommendations based on these findings.

METHOD

The method used in this research is a systematic literature review (Suherman et al., 2021). Data collection in this research was from Scopus-based data. The literature search used the keyword "scientific literacy" and was limited to searches within the last 5 years. Searches are also limited to Indonesia. Literature from Indonesia was selected because literature from other countries may not be suitable for implementation in Indonesia. This is caused by significant social, cultural, and educational differences, which can influence the effectiveness of efforts to increase scientific literacy. The stages used in the literature study can be seen in Figure 1,

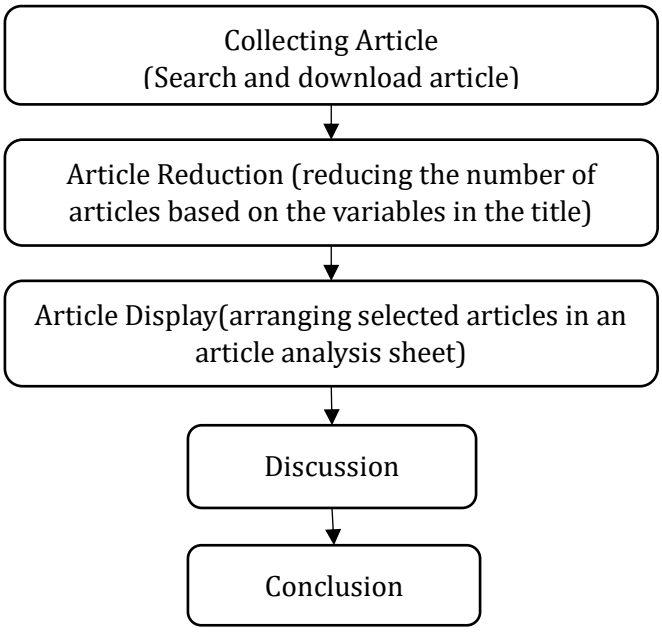

Figure 1. Stages of Literature Review

The first stage was a literature search. The literature that appears is then filtered to obtain relevant literature. The first number of articles obtained with the keyword "scientific literacy" in 5 years was 1355 documents. Then sorting was carried out by looking at the form of articles and excluding all books, and conference proceedings, then the results found were 894 documents. Finally, sorting was carried out for Indonesia alone and the results were 91 documents. Of the 91 documents, they were sorted again because some were not appropriate, such as literature study articles and bibliometrics. The final results obtained were 26 documents which were then analyzed qualitatively.

RESULTS AND DISCUSSION

Scientific literacy skills in Indonesia are relatively low, this can be seen from PISA data. Indonesia has not shown signs of significant progress, namely ranking 72nd in 2018, increasing to 68th out of 81 countries in 2022. This increase is the result of the operationalization of the 2013 curriculum, while the independent curriculum is still waiting for November 2024. Position Indonesia's ranking in the PISA assessment from 2000 to 2022 is shown in Figure 2.

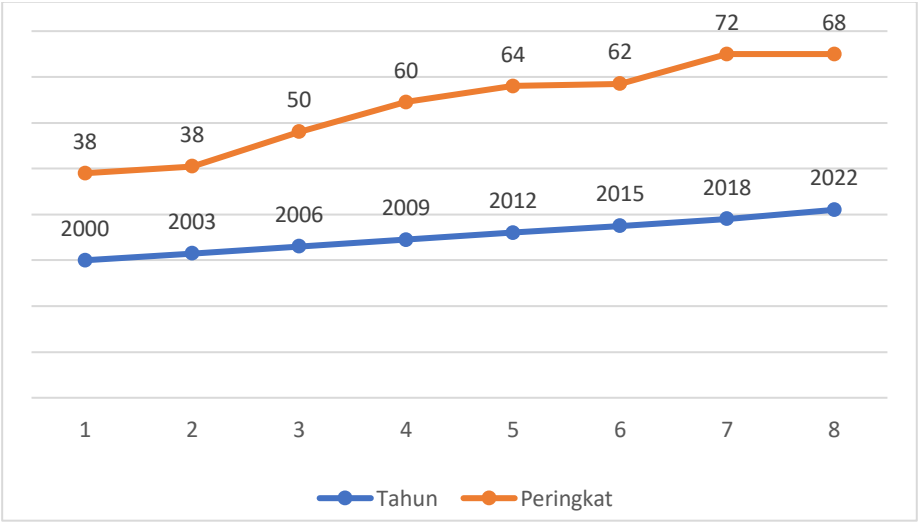

Figure 2. Graph of Indonesian Student Rankings in PISA 2000-2022 Source: OECD,2019

Based on the Indonesian PISA results shown in Figure 2, there was a decrease in scores in 2018 compared to 2015 in all areas assessed, namely reading, mathematics, and scientific literacy. This places Indonesia in 72nd place out of 77 participating countries. The decline in the PISA score is a concern, especially when compared with the international average score, where Indonesia lags by a fairly large margin. The average international PISA score in 2018 was 487 for reading and 489 for mathematics and science literacy. Indonesia has only managed to achieve a score above 400 twice, namely in the field of reading in 2009 with a score of 402, and in the field of scientific literacy in 2015 with a score of 403 (Yusmar & Fadilah, 2023).

Based on the literature data that has been summarized, 26 pieces of literature present efforts to increase scientific literacy. Table 1 is the summarized data.

Table 1. Literature Search Results

No	Research	Journal Name	Efforts to increase Scientific Literacy
1	(Adriyawati et al., 2020)	Universal Journal of Educational Research	STEAM Project Based Learning
2	(Jufrida et al., 2024)	International Journal of Evaluation and Research in Education	Ethnoscience Learning
3	(Suryanti et al., 2021)	International Journal of Interactive Mobile Technologies	Gadget-Based Interactive Multimedia on Socio-Scientific Issues
4	(Winarni et al., 2024)	Education and Information Technologies	Integration of STEAM and VR Using PjBL
5	(Lestari et al., 2024)	Journal of Education and Learning	Inquiry-Based Argumentation Teaching Model
6	(Rahmani et al., 2021)	Peuradeun Scientific Journal	Content and Creativity-Based Teaching Materials
7	(Yuliana et al., 2021)	Eurasian Journal of Educational Research	Picture Story Book with an Ethnoscience Theme
8	(Saija et al., 2022)	Indonesian Science Education Journal	Local Socio-Scientific Issues In OE3C Instructional Strategies
9	(Suryanti et al., 2024)	European Journal of Educational Research	STEAM Project Based Learning
10	(Lasmawan et al., 2023)	Pegem Egitim ve Ogretim Dergisi	*Nyerayo*-Based SETS Learning
11	(Fitria et al., 2023)	Eurasia Journal of Mathematics, Science and Technology Education	Digital Comic
12	(Subali et al., 2023)	International Journal of Evaluation and Research in Education	RE-STEM Aplication
13	(Ahied et al., 2020)	Indonesian Science Education Journal	Augmented Reality
14	(Simamora et al., 2022)	Journal of Curriculum and Teaching	BRADeR Learning Model
15	(Lestari et al., 2023)	Education and Information Technologies	Science Virtual Laboratory with Demonstration methods
16	(Bangun et al., 2023)	Pegem Egitim ve Ogretim Dergisi	Integrated Project Based Learning
17	(Mayub et al., 2023)	Indonesia Science Education Journal	Robotics Experiments
18	(Sholahuddin et al., 2023)	European Journal of Educational Research	Project Based Learning and Flipped Learning
19	(Dewi et al., 2021)	Journal of Turkish Science Education	Contextual Collaborative Learning Based on Ethnoscience
20	(Helıawatı et al., 2020)	Journal for the Education of Gifted Young Scientists	Teaching Materials Based on Content and Language Integrated

No	Research	Journal Name	Efforts to increase Scientific Literacy Learning
21	(Parno et al., 2020)	Indonesian Science Education Journal	PBL-stem and PBL
22	(Widodo et al., 2020)	Indonesian Science Education Journal	Gadget-Based Interactive Multimedia
23	(Kahar et al., 2022)	International Journal of Nonlinear Analysis and Applications	Inquiry-Based Integrated Learning Model
24	(Heliawati et al., 2022)	Indonesian Science Education Journal	Ethnochemistry-based Adobe Flash Learning Media
25	(Irwanto et al., 2024)	International Journal of Religion	Process-Oriented Guided Inquiry Learning
26	(Suwandi et al., 2024)	International Journal of Interdisciplinary Educational Studies	e-Modul Based on Discovery Learning with Scaffolding Questions

The table above contains research that focuses on increasing students' scientific literacy through various pedagogical and technological approaches. Research shows that the integration of technology in the learning process can have a significant impact on understanding complex science concepts. Following is an in-depth analysis of the main themes that emerged from the research, as well as the relevance and effectiveness of each approach based on existing literature.

STEAM Approach and Project-Based Learning (PjBL)

The integration of STEAM-PjBL in science education has proven effective in increasing the scientific literacy of students from various levels of education through qualitative and quasi-experimental methods. This approach uses practical projects such as miniature electric houses and space dioramas (Adriyawati et al., 2020), as well as technology such as virtual reality(VR) Winarni et al. (2024) to make learning more interactive and relevant. Research shows significant improvements in understanding of scientific concepts, critical thinking skills, and application of scientific knowledge in real contexts. In addition, project-based blended learning at universities also shows positive results (Bangun et al., 2023), indicating that this approach is beneficial at all levels of education.

Use of Technology in Scientific Learning

Various technologies in science learning have been applied to increase students' scientific literacy. Research by Suryanti et al. (2021) shows that gadget-based interactive multimedia has proven to be valid, practical, and effective in increasing the scientific literacy of elementary school students through socio-scientific issues (SSI), providing a more interesting and meaningful learning experience. Likewise, research by Ahied et al. (2020) augmented reality-based distance learning was also effective in increasing students' scientific literacy during the COVID-19 pandemic, with significant results in some classes despite challenging situations. In addition, Widodo et al. (2020) Gadget-based interactive multimedia is effective in increasing the scientific literacy of Generation Z, although students proposed improvements to the visual and audio aspects to make the learning experience more enjoyable. Research by Subali et al. (2023) shows that etno-STEM-based RE-STEM applications can improve students' scientific literacy by integrating local culture into science learning, making it more relevant and contextual. Apart from the validity and effectiveness of Discovery Learning-based e-modules combined with scaffolding, which has shown significant results in increasing students' scientific literacy on virus material (Suwandi et al., 2024). Overall, these studies highlight the importance of innovation in teaching methods and the use of technology to increase scientific literacy in various educational contexts, which not only improves understanding of scientific concepts but also increases student engagement and makes learning more interesting and relevant.

Ethnoscience Based Learning

Various ethnoscience-based learning approaches have been applied to increase students' scientific literacy, showing positive and significant results. Ethnoscience learning that connects local wisdom with scientific concepts can increase the scientific literacy of Grade 8 students in Muaro Jambi, although there is no significant difference between the classes tested (Jufrida et al., 2024). In addition, ethnoscience-themed picture story books in context-based learning (EthCBL) were more effective in increasing the scientific literacy of Grade 5 students compared to traditional teaching, with higher posttest results in the experimental group (Yuliana et al., 2021). Ethnoscience-based contextual collaborative learning also improves students' scientific literacy skills in the content, process, and attitude aspects of the medium category (Dewi et al., 2021). Lastly, the effectiveness of ethnochemistry-based Adobe Flash learning media shows a significant increase in students' scientific literacy on the concept of secondary metabolites, with a high level of user satisfaction (Heliawati et al., 2022).

Inquiry-Based Learning and Scientific Argumentation

This research examines various learning models that are effective in increasing students' scientific literacy in Indonesia, with a focus on inquiry-based approaches and STEM integration. (Lestari et al., 2024) proves the inquiry-based argumentation instructional model about the nature of science (IB-NOSA) is more effective than the guided inquiry and discovery learning models, with a significant increase in the scientific literacy scores of class VIII in Sleman, Yogyakarta. (Kahar et al., 2022) examined the influence of a guided inquiry model integrated with STEM on the scientific literacy of junior high school students, finding that this model was significantly more effective than the conventional model. Subsequent research, triggered by Indonesia's low scientific literacy according to PISA scores, evaluated the impact of the Process Oriented Guided Inquiry Learning (POGIL) model on students' chemical literacy in the topic of salt hydrolysis and the results showed that POGIL significantly increased the chemical literacy of class XI students in di Jakarta (Irwanto et al., 2024). Overall, these three studies emphasize the importance of using inquiry-based learning models and STEM and STEM integration in improving students' scientific literacy and propose the adoption of these models in educational curricula to achieve better results.

Development of Contextual and Creative Teaching Materials

The development of context-based and creative teaching materials is effective in increasing the scientific literacy of elementary school students, regarding human and animal movement organs material. The research used the Research and Development (R&D) method with the results of material experts' assessments showing aspects of content suitability at 90%, presentation at 78%, language at 83%, and creativity at 92%. Teacher responses show that these teaching materials facilitate science learning in a simple but meaningful way (Rahmani et al., 2021). In addition, Content and Language Integrated Learning (CLIL) based teaching materials on the Nature of Materials topic showed significant effectiveness with an increase in the literacy N-Gain 57%, and student responses were very good. CLIL has been proven to be effective in improving scientific literacy skills, including explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting data (Helıawatı et al., 2020). The development of digital comics based on scientific literacy on the topic of the growth of living things also significantly increased the scientific literacy scores of third-grade elementary school students. Quasi-experimental research shows that the use of interesting and contextual digital comics increases students' scientific literacy in experimental classes compared to control classes, suggesting further studies with more diverse subjects (Fitria et al., 2023).

Socio-Scientific Issues and Local Issues in Scientific Learning

The research (Saija et al., 2022) evaluated the OE3C methodology based on local socio-scientific issues (SSI) on 72 students of XI class in Indonesia, compared with 68 students taught with guided inquiry. Results showed that local SSI-based OE3C, significantly, improves students' scientific literacy, with 95.83% of students feeling their understanding has improved. This research recommends the integration of local SSI in chemistry classes to increase scientific literacy. Another study examined the *Nyerayo*-based Science, Environment, Technology, and Society (SETS) learning

model for elementary school students in South Aceh. Using a quasi-experimental method with 54 students, data were analyzed using an independent sample t-test. The results show that *Nyerayo*-based SETS learning significantly increases students' scientific literacy ($p < 0.05$) (Lasmawan et al., 2023). These findings emphasize the importance of using local contextual learning models to improve students' scientific literacy.

Learning with Experimental and Virtual Methods

The research (Lestari et al., 2023) evaluates the effectiveness of virtual laboratories combined with demonstration methods in increasing the scientific literacy of Junior High School students in Yogyakarta, Indonesia. A quasi-experimental method was used with a sample of 102 students divided into three groups: experimental group 1 (virtual laboratory and demonstration), experimental group 2 (virtual laboratory only), and control group (demonstration only). The results of the ANOVA analysis showed a significant difference between the pretest and posttest scores for scientific literacy abilities($F = 10.50$; $p < 0.05$) in each group. Experimental group 1 showed the most significant increase in scientific literacy with an effect size (partial eta squared) of 84.5%, compared to experimental group 2 (78.5%) and control group (74.3%). This concludes that virtual laboratories with demonstrations are the most effective method for increasing students' scientific literacy. Other research describes the impact of robotic experiments on scientific literacy, motivation to learn science, and responses of science teachers in several Junior High Schools in Bengkulu (Mayub et al., 2023). Experimental methods including interactive lectures, demonstrations, simulations, questions and answers, animation, and robot assembly were used in this research. Data was obtained through questionnaires and interviews with 100 students and 25 science teachers. The research results showed that robotic experiments increased students' motivation to learn science (score 4.02), and students' scientific literacy (score 3.99), and received a positive response from science teachers (score 3.98). the schools plan to continue robotic experiments to increase students' curiosity about science learning inside and outside the classroom.

Other Innovative Learning Models

The research (Sholahuddin et al., 2023) analyses the differences in scientific literacy between project-based flipped classrooms (PjBL-FC) and wetland-based project classes (PjBL) in class X SMA. The t-test results showed that the scientific literacy of students in the PjBL-FC class was better than, the students in the PjBL class A flipped classroom makes PjBL more efficient and effective, with almost all indicators reaching the high to very high category. Further study is needed for more investigation of the design, and implementation of this strategy. Preliminary research (Simamora et al., 2022) in 4 Pematangsiantar State Middle Schools shows that students' scientific literacy is still low due to traditional learning methods. The BRADeR learning model was developed to address this, combining the benefits of inquiry and SETS models. The validity of the BRADeR model was assessed through focus group discussions, it shows very valid results. This model can significantly increase the scientific literacy of junior high school students.

CONCLUSION

Various efforts to increase students' scientific literacy have been carried out through innovative approaches such as STEAM project-based learning, integration of ethnoscience, use of interactive technology, inquiry-based learning, scientific argumentation, and the development of creative and contextual teaching materials. These approaches have proven effective in improving scientific literacy skills by making learning more relevant, interactive, and interesting. Application of these approaches can significantly improve students' scientific literacy, enhancing their readiness to face future scientific and technological challenges. However, this research has not discussed further what efforts are most successful in increasing scientific literacy. Therefore, further research is recommended to examine the most effective to improve scientific literacy skills.

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